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Journal of the Society of Arts.

FRIDAY, APRIL 6, 1855.

CONVERSAZIONE.

On Saturday Evening the Society's Seventh Exhibition of Inventions was opened with a Conversazione, which was numerously attended by the members and their friends. About one thousand persons were present. Viscount Ebrington, M.P., Chairman of the Council, received the Company.

The Exhibition of Inventions is now open daily from ten till four. Admission free to members and their friends; to others on payment of 6d. each.

INTERNATIONAL COMMERCIAL LAW.

A deputation from the joint committee of the Society for the Encouragement of Arts, Manufactures, and Commerce, and of the Law Amendment Society, had an interview with Lord Stanley (of Alderley) on Friday last, at the Board of Trade, to present a memorial praying Her Majesty's Government to make known to the Imperial Government of France the interest with which a congress at Paris, to promote an approximation to an international system of commercial law, is viewed by the commercial public of Great Britain. The deputation consisted of Mr. W. Ewart, M.P., Colonel Sykes, F.R.S., Mr. W. Hawes, Dr. Waddilove, Mr. T. Winkworth, Mr. Leone Levi, and Mr. Le Neve Foster (Secretary.)

Lord Stanley (of Alderley) expressed himself as fully impressed with the importance of the subject brought to his notice by the Deputation, and assured them that he would not fail to confer with the Earl of Clarendon and the other members of Her Majesty's Government, as to how far assistance could be given to bring the subject to the favourable notice of the Imperial Government of France.

SIXTEENTH ORDINARY MEETING.

WEDNESDAY, APRIL 4, 1855.

The Sixteenth Ordinary Meeting of the One Hundred and First Session, was held on Wednesday evening, the 4th inst., Dr. T. K. Chambers, Chairman of the Industrial Pathology Committee presided.

The following Candidates were balloted for, and duly elected Ordinary Members:—

Cape, George Augustus, jun.	Merrifield, Chas. Watkins
Clarke, Hyde, D.C.L.	Ottley, George
Denton, J. Bailey	Wilson, Samuel King
Fowler, John, jun.	

The Paper read was

ON THE DISEASES OF MINERS.

BY HERBERT MACKWORTH.

In taking up this important branch of the pathological investigations set in motion by the Society of Arts, and in giving a sketch of the condition of those whose toil is in the hidden places of the earth, a tribute is due to the encouragement afforded by the Society at all periods since its formation, to improvements directed to the amelioration of the physical condition of the miner.

I may especially refer to the premium given in 1816, to Mr. John Taylor, for an improved ventilating machine, which may be said to have been the basis of the mechanical ventilation now so largely applied in Belgian mines, and to the liberal premium to Mr. John Ryan, for improvements in ventilation, the principle of which, though little applied in England, has since, in a modified form, been incorporated into the mining laws of the principal continental mining states.

No one who has associated much with miners, or employed, as I have, considerable numbers of the various classes under which they fall, coal, iron, copper, tin, and lead miners, can fail to be struck with their appearance and general physical characteristics, as different from those of other classes of workmen inhabiting the same localities. It is remarkable that this large population, numbering by the last census, 296,461, following a peculiar and interesting occupation, has not attracted, by any means, to the same degree as on the Continent, the attention of medical writers, and that if we except the able reports of Dr. Barham, Dr. Mitchell, &c., to the Children's Employment Commission, we are actually without any comprehensive physiological treatise, such as those of Hanot, Vandenbroeck, Brockmann, and others; and it may be asserted that little more is known of the deplorable evils under which this class of workmen labours, than is given in the reports made in 1842, to which I have alluded.

The various committees of Parliament which have instituted inquiries since that time, have been satisfied to direct their labours towards a fraction only of these mines, and of these evils; either omitting altogether, or briefly referring to the enormous number of non-fatal accidents, the excessive proportion of sickness which falls to the lot of the miner, and the peculiar diseases and influences which prey on a miner's strength, and bow him down to the grave at an age when other labourers are in the vigour of life and strength.

The serious waste of our mining population from these causes, and the consequent drain on other classes, the rate of wages; the cost of mining; the demand for minerals of all kinds; apart even from motives of humanity, render the subject of mitigating or averting accident and disease from miners, one of national importance.

It is not by visiting the large mines, or by reading the evidence given by their managers, that a correct appreciation can be obtained of the hardships of a miner's life; it can only be obtained by those who have visited that greatly preponderating class, which the proprietors never visit, where no medical man enters, and where foremen and workmen are, in the face of dangers and difficulties, left in that untutored state which we see on the surface in populous towns, constantly converting a perhaps naturally healthy site to a sink of impurity and disease.

In attempting a feeble pourtrayal of a subject embracing so many topics as the pathology of miners, my remarks must necessarily be more superficial and general than I could desire, but I trust never to lose sight of the practical bearings of each question, and of the economic value to the masters as to the men, of remedial measures. As the various kinds of mines will require, in some points, separate treatment, their relative importance may be classed according to the numbers employed in 1851:

			Production in 1852 about
Coal Miners	216,366	...	52,000,000 tons.
Iron Miners	27,098	...	2,250,000 tons.
Lead Miners	21,617	...	65,000 tons.
Copper Miners	18,468	...	11,000 tons.
Tin Miners	12,912	...	9,000 tons of ore.

Minerals lie in beds, lodes, or veins. Coal mines are worked almost entirely in beds, lying generally rather horizontal, but in other cases at every conceivable angle. A lode may for the present be taken as a bed lying at a steep angle. Veins, strictly speaking, are threads of mineral matter, which the miner follows until they enlarge into bunches, rooms, &c.

Copper and tin lie chiefly in lodes; iron and lead in beds and veins; but as the object is to get out a certain quantity of minerals with the least labour, many coal, iron, copper, and tin mines are worked on a similar plan; the chief differences being that a coal mine generally consists of two shafts, sunk down on to a bed, whilst in copper and tin mines the lode is turned on end, so that the numerous openings from the surface are in the lode itself. In coal mines large quantities have to be brought out rapidly from great distances underground. It is evident, therefore, that coal miners are further removed from the surface atmosphere than most other miners, and that consequently the ventilation of their working places is more difficult, if difficult it may be called.

The conditions which pervade all mines are, that a miner excavates a tunnel or space before him sufficiently wide to allow him to work and progress in the cheapest manner. This excavation serves for the extraction of the materials by means of boxes or trams, for carrying off the springs of water met with, and for bringing in to him a supply of atmospheric air sufficient to keep his light burning. As he penetrates deep into the earth's crust, the minerals are brought in a horizontal direction to the bottom of a highly inclined or vertical shaft, through which they are raised to the surface.

Hence, there are three distinct portions of a mine, the shafts, the underground roads or ways, and the variety of working places at their extremities, which have to be considered in relation to the occupation followed in them. All of them are distinguished from other workshops by the peculiarities of the temperature, pressure, moisture, and composition of the air, of the gases, and miasmata which exist in them; by the absence of sunlight, and by the mode of lighting, quite as much as the motions and working positions are different from those belonging to any other occupation. In the deeper parts of his operations, the miner is liable to be stopped or overwhelmed by water or carbonic acid; in the higher parts he may be suffocated or destroyed by irrespirable and explosive gases; and if he enters but a very short distance beyond the supplying current of atmospheric air, the oxygen rapidly falls below the proportion necessary to support life.

In the coal, and in some of the ironstone mines in England, it is the custom for the workmen to ascend and descend the shafts by ropes and chains. In the other mines the miner has access to his working place by ladders. The effect on the health and lives of miners, by having to ascend many 100 yards of almost perpendicular ladders at the end of a day's work, appears to be very serious from the able investigation of members of the Royal Cornwall Polytechnic Society,—Dr. Carlyon, Dr. Barham, Messrs. Lanyon, Blee, and others.

The muscles usually in full action in breathing, being tensely contracted, and the compression of the air in the lungs forming a fulcrum for the development of the force necessary to draw up the body, the minute air vessels of the lungs are very subject to injury during so prolonged an exertion, following on the completion of the daily task. The mischief done to the principal vital functions is still further aggravated by the want of ventilation in many ladder shafts, and in others by their serving as upcast shafts, that is, to bring the air out of the mine loaded with all the impurities collected in its course. I can speak from experience in the deep coal mines of Belgium, and the North of France, and in Saxony, as well as in this country. It is the opinion of the chief medical authorities, that climbing ladders in these shafts strike the first death-blow to the constitution of a large class of miners. The more enlightened managers of mines are aware both of the sacrifice of life and health, and the sacrifice of a considerable portion of the labour, enhancing the cost of working deep mines either by an actual payment for each transit, or a diminution of the daily task. This loss I have heard variously estimated at from $\frac{1}{4}$th to $\frac{1}{3}$th of the ordinary labour. Converting the ladder shaft into a downcast instead of an upcast; placing open timber sollers or landings, so as not to check the ventilation; or, as is done in Belgium, constructing them of iron bars, shortening the length of each ladder to 20 or 30 feet; making the rounds 8 or 10 inches apart, in lieu of 12 or 14; and inclining the ladders at an angle not exceeding 85°, are the praiseworthy means adopted by some proprietors to diminish this evil.

But the merit of the introduction of the fahrkunst o the Hartz mines, or man machine, as it is called in Cornwall, by which 100 men can at one time ascend without exertion and with great safety from their work, is due to Sir Charles Lemon and the members of the Cornwall Polytechnic Society. Three of these man-engines are now at work, at the United Mines, Tresavean, and Fowey Consols.

At the first of these mines Captain Francis showed, in a Report of 1845, that, deducting the cost of working the engine from the half hour per day saved to 450 men and 50 boys, there was a clear saving of £800 per annum, which would, in 3 years, pay the cost of the machine, without reckoning the saving in labour. "The relief afforded to the miners by this machinery can scarcely be estimated, and can only be fully appreciated by those who, after having nearly their whole strength and spirits exhausted by working for 8 hours, and even longer in some instances, in an atmosphere varying in temperature from 95° to 105° Fahrenheit, had formerly to climb to the surface by ladders. The amount of physical suffering which it alleviates is almost incalculable, and this benefit would, of itself, be full compensation for the outlay incurred in its erection, but the advantages, in a pecuniary point of view, which it affords, are equally striking."

The single acting man-machine consists of a strong rod of wood or iron, extending the whole depth of the shaft, to which are fixed platforms, about 4 feet by 2½ feet, at intervals of 10 feet. There are corresponding platforms fixed at the same distances to the sides of the shaft. The rod has a reciprocating motion up and down of 10 feet, communicated to it by the crank of a water wheel or steam engine. Now, a person stepping on the rod when it is about to go up, and off it on to the side platform when it is about to go down, and repeating the operation at every stroke of the rod, would arrive without effort at the top. One man can be on each platform at a time. In the double machine there are 2 rods, which move up and down alternately, and, therefore, double the speed of the ascent.

At Mariemont, in Belgium, the best example of a man-machine is to be found, but in many parts of France, Belgium, Westphalia, and Saxony, these machines are coming into general use, where the mines are deep and the number of miners who have to ascend considerable. At Mariemont, several mines communicate underground, for the purpose of getting access to the man machine. It has also been shown in Westphalia that a considerable saving may be effected by the employment of a man-machine, instead of raising and lowering the miners by ropes. It is therefore evident that it is in the power of proprietors of mines, by a remunerative outlay of capital, to preserve the workmen from what has been expressively termed "the miner's anticipatory tomb."

The roads by which the minerals are brought from the working parts to the shafts, vary in dimensions according to the inclination or thickness of the bed of rock. 4ft. 6in. is a common height for the branch road in driving through barren ground in metallic mines. In Cornwall, the levels vary generally from 5 ft. high, and 2 ft. wide, to 6 ft. high, and 4 ft. 6 in. wide. But the roads are seldom made so low in the above mines as in many of the ironstone and in some of the coal mines, where the height of the road is made to depend on the height of the seam. There are coal mines in Yorkshire, near Bristol, and in many other parts of England, where the whole thickness of ground taken out for the man to work in, is 15 inches. In this height the miner has to work with his pick in "holing" under the coal,—the technical expression for picking out a thin wedge of ground from under the seam, so that the coal, by its own weight, or by driving wedges in to the upper part, will become detached. In this height of 15 inches, it has to be piled into small boxes on sledges, and drawn or pushed by boys down a slope to the level, which is rather higher. The position of the boys in this "hurrying," "pulling," or "carting" (for every mining district has its own term,) is almost horizontal; the work that falls to their share is exceedingly laborious, and disproportioned to their age and strength. The height through which the "hurriers" have to push the trams, frequently does not exceed 30 inches. Here they harness themselves in front of the train by a leathern belt on the hips, and a chain between the legs, or push behind, assisting, when the top is low, by resting the head against the end of the tram. The mines in which this system is carried on are generally in the most neglected state: neither proprietors nor any person of superior intelligence enters the mine, and I generally find the drainage and ventilation in a deplorable state. Conceive the effect of the constrained attitude, laborious exertion in so contracted a space, half a mile away from the atmosphere, and the faces of these boys between 10 and 15 years of age, within a few inches of pools of mud and water, in which are worked up the putrefactions and nuisances of years. This is generally acknowledged to be the most costly method of working a colliery, the price of hauling being even 18d. per ton more than in other mines. I have met with instances where 75 men were ordinarily employed in the extraction of 30 tons of coal per day. Improvements in mining, slowly as they are imitated, are somewhat reducing the proportionate number of these mines. I have never met with any seam of coal in which the cost of cutting out the roadway to a height of 40 or 42 inches, and employing small ponies for the heaviest portion of the work, of which there are large numbers in the North of England mines, would not amply repay an expense often more imaginary than real.

Dr. Copland states: "Working in constrained positions shows its effect most decidedly in miners and colliers, who labour chiefly in the sitting or kneeling posture, frequently with the body bent in the greatest degree, in an unnatural atmosphere, often containing carburetted hydrogen and carbonic acid gases, and with artificial light. They are, moreover, exposed to changes of air, and occasionally work with their feet in water. They are generally spare men, with slightly curved spine and bow legs. When the dirt with which their skin is usually loaded is removed, the complexion seems sallow and unhealthy. Their complaints are asthma, rheumatism, disorders of the head, intolerance of light, &c., evidently resulting from the circumstances just stated connected with their employment, and their exclusion from the beneficial influence of sunshine, light, and air. They are not generally very intemperate, and yet they seldom live beyond fifty."

In the thin seams, the body of the collier is usually bent up, so that the elbow may rest either on his knee or thigh, to prevent the abrasion of the joint which would occur if rested on the ground whilst he is working with his pick. His candle he places rather behind him; occasionally he sticks it in his cap. A Cornishman can drive a gallery in rock, 2 feet high, by 2 feet 6 inches wide. Cornish miners are more accustomed than others to work over their heads, in driving upwards the small underground shaft, or in bringing down the ore; and for this reason, chiefly, they present much muscular development about the shoulders. All these are positions in which breathing is accompanied with increased effort, even in a pure atmosphere, and yet they occur in places where, without constant attention, pure air will not penetrate. The "hurriers" are in one respect fortunate that their journey to and fro bring them into the current of air, where some renewal, at least, is going on.

The degree to which physical defects prevail amongst young colliers of 18 years of age, may be illustrated by the fact that, in the neighbourhood of Liège, out of every 100 colliers drawn for the militia, 42·5 were rejected for physical reasons; of 100 nailers, 36; of printers, 22; of weavers, 21;—the rejected out of the whole district averaging 26 per cent.

Although man can bear for a short time, without serious inconvenience, temperatures varying from 50° to 300° Fahrenheit, and pressures of three or four atmospheres, as in a diving bell, or of only ½ an atmosphere as on the summit of Mont Blanc; we perceive by the physical differences of races inhabiting the temperate and torrid zones, mountainous districts, or flat countries nearly level with the sea, how large an effect on the human frame comparatively small atmospheric differences may produce. We may go further, and venture to infer from the beautiful foresight with which nature has hedged round the composition of the atmosphere (on mountain or in valley, at the equator or the pole, invariably the same) that very minute differences of the oxygen it contains, or accessions of foreign constituents may be expected to produce a powerful effect on all the animal organisations which are linked with the operation of breathing.

The temperature of the rocks which the miner has to penetrate increase in depth according to a somewhat uniform ratio, but varying according to the description of rock passed through. The extensive experiments of Mr. Henwood, conducted in the Cornish mines, are summed up in the following table, which exhibits the difference between the temperatures of granite and slate rocks:—

Depth in fathoms of place of observation.	Temperature. In Slate. ° Fahr.	In Granite. ° Fahr.
Surface to 50	57	51·6
50 to 100	61·3	55·8
100 to 150	68	65·5
150 to 200	78	—
200 and upwards	85·6	81·3

The temperature of the water issuing from the artesian well of Grenelle, 600 yards in depth, is 820°, being an increase of 1° per 59 feet in depth. The result of a series of experiments at the Dukinfield deep pit, in Lancashire, gives 1° per 51 feet as the increment of temperature. A shaft, 126 yards deep, in Siberia, gave 1° degree for every 30 feet. The experiments on the rock in coal mines have not generally been conducted with that extreme care necessary to ensure accuracy.

The effect of this temperature on the working places of the miners is much modified by the water flowing in, and varying in temperature from about 46° when it comes direct from the surface, up to 106°, as was observed at a depth of 500 yards in the United Mines, Gwennap. 94 gallons of water per minute, poured in from this spring, whilst at a distance of only 3½ feet, another spring from the other side of the lode discharged water at a temperature of 98° to the amount of 30 gallons per minute. The temperature of the air in the working places of mines I find to be exceedingly variable, but frequently very much higher in the metallic mines than in the coal mines, although M. Von Dechen finds the increase of the temperature of the rock in the Rhenish coal mines more rapid than in metalliferous ones. The temperature of working places has seldom been observed so high as in

the United Mines. The labour of working in this place was so great that the men had to be changed every five minutes, and they threw themselves six or eight times a day into cold water to refresh their exhausted frames. The cost of driving the level under these circumstances, as was afterwards shown, was actually trebled. In the Consolidated Mines the air has been observed at a temperature of 98° at a depth of 630 yards, and in the Tresavean Mine, of 95° at 640 yards. The remarks in a short paper of mine, read before this Society on the 11th of August last year will have shown that the excess of temperature beyond 75° in these extreme cases, in any working place, is due solely to the ignorance or neglect of the simplest rules of ventilation. The temperature of the "ends" of metalliferous mines is generally between 75° and 90°, which is due to the air being so long stagnant that the combustion of the lights and the heat given off from the bodies of the workmen (assumed to be at the normal temperature of 98°), is able to raise its temperature from 15° to 30°, notwithstanding the cooling influences of the surfaces of rock. From a number of observations I have found that no part of a well-ventilated mine in the summer time exceeds 68° at a depth of 300 yards. The return air of such coal mines about, and exceeding, that depth, varies from 62° to 68°. In coal mines which are not well ventilated the temperature of the ends is frequently between 70° and 80°, although the thermometer at the surface may be at the freezing point.

By a judicious use of the thermometer, and observing its gradual rise in walking from the downcast shafts to the working places, the localities of defective ventilation may be detected, as well as leakages of impure air which might otherwise escape observation.

In districts where ventilation is not understood, it is commonly asserted by miners and others that the deeper the mine the more difficult the ventilation, when, as will presently be shown, the contrary is the case. Many parts of the deep metalliferous mines are worked at a loss, or altogether abandoned in consequence of the poor air and high temperature. That this is not due to the heat communicated by the rock, however deep the shaft, or to the thousands of yards which it may be indispensable for the air to travel before it reaches the miners, may be illustrated by an experiment at the Seaton Colliery, made by Mr. Nicholas Wood, the air at the surface being 44°.

The shaft was 520 yards deep, and 14 feet in diameter, divided by an air-tight brattice, or division. The length of the air-course underground was 1,012 yards, and the area of the passage 24 square feet. The surface of the air-course exposed to the air was 60,720 square feet, at a temperature probably of 80°. 7,002 cubic feet of air per minute passed through the air-course, and although it took 20 minutes to travel from shaft to shaft, its temperature was only raised from 49½° to 52½°, that is, by three degrees. The air gained 5½° in descending, according to the usual rule of 1° increase in temperature for every 300 feet of descent, due to the increased pressure of the air, but which it again lost on returning to the surface, where it exhibited a temperature of 46°.

In the ends, where miners work, there is often a difference of 3° or 4° between the warmth of the air at their feet and at their heads, where the function of respiration is going on; one example of the imperfect diffusion of gases which takes place, but a means of assisting the circulation of the air, provided the main current were brought close to the workman.

In hot mines the men are more subject to take cold, either from passing to and fro into the cooler incoming air, or in standing about the top of the shaft previously to going home. The boys between 10 and 15, who bring out the coal from the working places, are in a perpetual change of temperature, often of 30° every few minutes, and consequently suffer in a high degree from pulmonary complaints. I have said enough to convince the manager of a mine of the loss of work caused by an increase of a few degrees of temperature, I will only add the opinion of Monsieur Coulomb:— "I have caused," he says, "extensive works to be executed by the troops at Martinico, where the thermometer is seldom lower than 77° of Fahrenheit. I have executed works of the same kind by the troops in France, and I can affirm, that under the 14th degree of latitude, where men are almost always covered with perspiration, they are not capable of doing half the work they could perform in our climate."

Numerous observations with the hygrometer in Belgium and England, exhibit the fact that the current of air, however dry it may have entered, after it has passed through the workings, is nearly at the point of saturation. The worse the ventilation, the greater the amount of moisture.

A working man exhales and throws off in perspiration from 6 to 8lbs. of water per day. Horses perspire more profusely than other animals. To be added to this is the moisture acquired by the air in descending or traversing wet shafts and airways, or derived from the combustion of the lights and gunpowder.

Dr. Hanot remarks, "This condition of the atmosphere is one of the most hurtful to the animal economy; the various functions languish, the tissues become relaxed, the fluids of the human body tend to escape in consequence of the accumulation of caloric, and soon the perspiration which the air, already charged with humidity, is unable to carry off, streams down the bodies of those working under these influences." A remark confirmed by the experiments of Bertolet and Laroche.

It is well-known that high temperatures accompanied with moisture, especially rapid changes of them, are extremely productive of disease amongst artisans. Moisture is the very common vehicle in which other agents of disease are dissolved, and brought into action with greater intensity. These facts have an important bearing, when we consider the amount of malaria now pervading the air of mines. It is sufficiently evident that to obtain the greatest amount of work from a man in a given time, it is necessary to supply air, not only cool, but tolerably dry. This can be effected in almost every mine by a moderate amount of ventilation when properly distributed.

The action of breathing has been called the ventilation of the blood. The expansion of the chest caused by the powerful muscles, which belong to the action of the lungs, produces a partial vacuum sufficient to draw in a proportion equal to about $\frac{1}{10}$th of the air already contained in the chest. By a rapid diffusion of the gases, the oxygen is brought into contact with those delicate labyrinthine tissues, (the surface of which is variously estimated at from 15 to 400 square feet,) where the oxidation of the particles in the blood is effected.

The average of a number of experiments (by Vierordt, Liebig, Lehmann, &c.) gives 320 cubic inches as the quantity of air inhaled per minute, of which 10 per cent., consisting of oxygen, is consumed by the lungs, and from 7·7 to 8·5 parts of carbonic acid gas are expired.

The oxygen inhaled produces a slow combustion, and, the oxidation in the process of breathing causes a mild and genial warmth throughout the frame. All vital activity, according to Liebig, is derived from the mutual action of the oxygen and food. The 14 oz. of carbon which are burnt into carbonic acid daily, must be taken in food. A horse burns 97 oz. daily, consuming for this purpose 13 lb. 3 oz. of oxygen. The food, therefore, should be in direct ratio with the supply of oxygen. These conditions, joined with a due proportion of sleep, enable a man to perform a daily task equivalent to carrying 30 lbs. a distance of 72,000 feet. Any causes which disturb this balance produce a diminution in the average amount of work performed.

According to the experiments of Dr. Wehrle, the oxygen consumed by a candle per minute amounts to 16·6 cubic inches, and the carbonic acid formed, to 4·2.

When the quantity of oxygen is reduced from 21 per cent. to 18 or 16, an ordinary miner's light is extinguished; an Argand lamp will burn until the proportion is reduced to 14 per cent.

According to the analysis, by Professor Hunt, of air from the Consolidated Mines, the amounts of oxygen were respectively 16·25, 17, 17·50, 19·15, 18, and 17·75 per cent. The average of 18 samples of air taken from different mines in Cornwall was

Oxygen	17·067	per cent.
Nitrogen	82·848	,,
Carbonic acid	·085	,,

Of six others—

Oxygen	19·34	per cent.
Nitrogen	78·75	,,
Carbonic acid	1·90	,,

It is suggested that the quantities of carbonic acid in these cases may have been actually larger, being partly absorbed during the experiments. Traces of sulphuretted hydrogen, and sulphurous acid were also found.

In the mines of the Hartz, the following are the results of accurate analysis:—

1st place—	1·86	per cent. oxygen	X	1·8 per cent.	carbonic acid gas.
2nd	1·94	,,	X	1·77	,,
3rd	0·73	,,	X	1·04	,,
4th	2·29	,,	X	2·38	,,
5th	0·29	,,	X	0·65	,,
6th	0.21	,,	X	0·72	,,

In all of these cases candles would burn, and Nos. 3 and 5 were considered samples of tolerable ventilation.

It has been approximately determined that a deficiency of oxygen of 10 per cent., or an excess of carbonic acid gas amounting to 8 per cent., will quickly produce stupor, and eventually death. I have frequently met with instances in mines where the men were obliged to work in the dark from want of ventilation, some being pointed out to me who were particularly good hands at it, and I have had occasionally to spend the night in parts of mines where the candles will only keep alight by being tied two or three together and held horizontally. A few months ago, the manager of a colliery was killed by remaining ten minutes in a place where the men had at last refused to work. Defects in the atmosphere of smaller amount the miners do not feel, except in the sensation of lassitude, and difficulty of prolonged exertion.

Their exclusive attention is directed to keep the candles burning, a very necessary caution, for in passing slowly through the air in the roadways, my candle has sometimes gone out ten or twenty times, and I have seldom visited mines not containing explosive gases where there was sufficient oxygen to keep a light burning throughout the parts in work. These, then, are the ordinary limits within which a miner has not only to live, but to carry on a laborious occupation. The ordinary practice is to drive on a gallery or opening as far from the current of air as the condition of light will permit, varying from 20 to 100 yards, as it is termed, "in advance of the air." I have contrived a portable spirit lamp, by which the air in each working place can be at once analysed, or rather the point reached by the miners between perfect combustion and the extinction of the light can be determined. It consists simply in providing an airtight cover to the glass cylinder, capable of being shut instantaneously. The time in seconds is noted which the lamp takes to go out, first, in pure air at the bottom of the pit, and afterwards in the working places. The lamp having been ascertained endiometrically to go out with a certain deficiency of oxygen, and excess of carbonic acid, these will be in proportion to the difference of the squares of the times registered.

It is very certain that the deficiency of oxygen acts injuriously on the miner before he is able to appreciate with his eye the diminished intensity of the light of the candle. According to Dr. Bird, a deficiency of 2 per cent. has in some cases been known to be destructive to animal life. M. Gonot and other engineers have remarked that the diffusion of gases does not proceed so rapidly underground as on the surface. I have certainly met with many instances where a light will burn at the feet, and go out if raised up to the head, or it will go out only in the highest parts of the works. In other instances carbonic acid gas, air, and fire-damp may be found in successive strata at the same spot. It must be recollected that a miner works in the lowest possible room, in such conditions as would be felt by a person confined in the upper part of a close room in which many persons were congregated, except that in the former case he is a long way from the atmosphere.

The story of the 56 monkeys dying in the Zoological Gardens in a large domed roof, ventilated only along the floor, will be familiar to many, and illustrates the effect on animals of living in a stagnant atmosphere, such as that to which a miner is unnecessarily condemned. One remark, made I believe universally during the cholera epidemic, pointed to the want of through ventilation in houses, as the distinguishing mark of those visited with its severest attacks. The opinions as to a large amount of disease being caused amongst miners by the deficiency of the vital element, have been so universally expressed by medical men, mining engineers, and others who have carefully investigated the subject, that I need only refer to the commission of 1842, the numerous papers read before the scientific societies in Cornwall, and indeed all medical treatises on miners. One observation of Dr. Hanot is worth recording: "Placed in favourable circumstances for observing two kinds of working miners in two distinct kinds of coal mines, the colliers of Dur, where the ventilation is good, and those of Flenu, where it is slow, and often neglected, I have arrived at the conviction that there existed among them an external physical difference readily appreciated by the eye, to such a degree that I could point by the finger when surrounded by workmen to those who work at one, or at the other description of mine."

The dust which floats in the air, more particularly of some colleries, is often referred to as productive of permanent injury; but more accurate observations have determined that melanosis, and other affections which may result from it, are also produced in other mines, and are attributable rather to the carbon arising from the imperfect combustion of tallow or oil of bad quality. This disease seldom, if ever, occurs amongst men working in coal dust on the surface. The disease to which I have alluded has been often described, although it has not been thoroughly understood. It prevents the free access of oxygen to act on the blood, and it appears, after a time, as if carbon was actually formed in the lungs. I have known instances of a cloud of dust alone having produced suffocation. In one instance the person inhaled unconsciously the dust brought by a rapid current of air from the upsetting of a tram; in another, two men were found dead in a ladder shaft, with their candles still alight, but covered with dust thrown up by an explosion of fire-damp. It is, in my opinion, to the hot fiery dust which accompanies such explosions that the number of deaths from suffocation, amounting often to seventy per cent. of the whole number of killed, is chiefly to be attributed. Whilst investigating the circumstances attending a large number of explosions, I have found several instances of men who had placed a wetted cap or handkerchief to the face, having come out from the extremities of the mine, passing over the dead bodies of their companions. On the other hand, I have not met with any instance of men having been found dead who have adopted this simple means of safety.

Deprived, as a miner is, of the beneficial rays of sunlight for six days out of seven, at least in the winter months, we cannot altogether reject the idea that he permanently suffers from this cause, although it is one difficult to estimate. The shady side of a street, under some circumstances, is more unhealthy than the other, and individuals labouring under asthmatic complaints are very sensitive

to the action of light, but much, no doubt, is due to the heating rays.

This has been used as an argument, and with some justice, for working two shifts or changes of men underground, the first from 4 a.m. until 12, and the second from 12 till 8 p.m. The mining engineers in Belgium are, however, mostly of opinion that the night-work in their mines is preferable to the day-work, and does not present serious inconveniences to the young miners. One of the arguments used, being that from the atmosphere being cooler the ventilation is better by night than by day.

In considering the absorption of oxygen by the various chemical changes which go on in mines, whether by breathing, combustion, or by the decomposition of vegetable and mineral matters, it must be noticed that a double deterioration is caused, increasing the proportion of nitrogen, in addition to that of carbonic acid or other gases of a poisonous nature. The action of nitrogen on the human frame admits of more close investigation than it has hitherto received. It appears sometimes to be absorbed by the lungs in small quantities; at other times given off. Its excess in any atmosphere is not believed to be actively injurious to the vital functions. On the other hand an excess of carbonic acid above $\frac{1}{250}$ in the surface atmosphere begins to exercise an injurious effect, and the presence of 1 per cent. indicates a very unhealthy atmosphere. What, then, must be the effect in those mines where I frequently find openings left from the old workings into the downcast shaft, or the commencement of the air course for the free percolation of carbonic acid gas (variously termed choke-damp, black-damp, stythe, or sulphur) into the incoming vital current in sufficient quantity to extinguish a candle at the part where it enters? These old workings, technically called goafs, or deads, are vast laboratories for the decomposition of minerals, timber, and animal remains their principal products are carbonic acid gas, sulphuretted hydrogen, and mineral salts. Lead mines, especially those in the carboniferous limestones, seem to give off considerable quantities of carbonic acid gas, but the most remarkable mine probably in this respect is the Pontgibaud, in the Puy de Dome, where on the first starting of the pumps, the pressure of the gas was sufficient to raise the water in a fountain five or six yards in height.

Men are occasionally suffocated by carburetted hydrogen in entering goaves. Where this gas exists, it is essential that the higher side of the goaf especially should be swept by a current of air. No old working should be entered in which a light will not burn. Explosive gases sometimes exist unsuspected in these places, and the examinations should, therefore, be made by the safety lamp. If it will not burn, an endeavour should be made to ventilate the place. If this happen to be a shaft or well, the most immediate means are to throw down repeatedly water, or a bundle of straw fastened to a rope.

The next most important gas met with is sulphuretted hydrogen. It proceeds from some mineral combinations, and the excrementitious matters which necessarily accumulate in the neighbourhood of working roads or places inhabited for many years continuously. It exercises an extremely deleterious action on the respiratory functions; it is the most active of the gaseous poisons. It seems to act upon the blood in depriving it of some of the elements necessary for proper respiration. It is lighter than air, $\frac{1}{1100}$th is supposed to act injuriously on the constitution; $\frac{1}{770}$th has been known to kill a horse; $\frac{1}{1100}$th a bird. It exists in some proportion in the air of very many mines, and is commonly termed White Damp. It explodes at a lower temperature than fire-damp, and the ordinary Davy lamp is, therefore, not a sufficient protection. Occasionally it commits great ravages on the health of the workmen. A medical record exists of its effects some years ago, at the mines of Anzin; at No. 4, Vanneaux, Wasmes, Turlupu, and Jemmapes. At Vanneaux, the water dropping from the roof of the mine raised blisters on the skin.

Blasting with gunpowder consumes oxygen, and gives off a variety of gases. According to one estimate, two miners working an eight-hours' shift or change (Germanicè *schicht*), give off:—

By breathing.....	1·53 lbs.	carbonic acid gas.	
From oil lamps.....	1·03 ,,	,,	,,
From blasting	·56 ,,	,,	,,

In addition to the gases already enumerated, carbonic oxide and compounds of hydrogen are produced by blasting. The solid particles of combinations of potassium float in the air and cause the smoke, which, under a system of ventilation having economy for its object, should be at once removed.

I need not enter at length into the variety of exhalations and miasmata proceeding from the putrid fermentations of animal and vegetable matters underground, as they are well known upon the surface; but in these confined channels the accumulation is heaped up at every step, and the warm moist atmosphere gives every facility to them to produce their direst effect. However careful each man may be in covering the deposit (46 lbs. of solid excrement per man per year), from 300 or 400 men in and around the working-places, and in the dead ends which the current of air passes, it cannot but supply a fertile source of miasmata. In some populous mining villages, there are from 20 to 50 houses to one privy, which unmistakeably adds to the nuisances underground. If there is a stable and accumulated dungheap, it is almost certain to be placed close to the incoming air, in which also the horses stand, or are constantly working to and fro. A forest almost of timber, used for supporting the roof and sides, is undergoing dry rot, which, under bad ventilation, consumes it in two years. The existence of these nuisances is not so appreciable to the smell as it would be on the surface, even on entering the receptacles themselves, a peculiarity arising from the solvent power of the moist air; but their effect may best be understood by imagining a town supplied with air by a culvert, which passed through most of the streets in succession, but leaving each house to be ventilated solely by a diffusion of gases very slow in action, and the only escape from nuisances being to cover them. Add to this the other noxious gases which I have named, and a conclusion may be drawn as to the condition of mines, and its destructive consequences to economy of labour as well as health, when they belong to proprietors who never go into them, and are left to the charge of managers who know or "care for none of these things."

I shall hereafter show the requirements necessary for mitigating these evils to the greatest possible amount. I will only now refer to two sanitary rules. The stables should be kept clean and whitewashed, and be ventilated by a separate current, technically, split of air, passing on to the return air-course without supplying the miners. I have known nearly the whole of the horses in a mine die from the stables being allowed to accumulate filth. The horses in mines generally thrive well, as they work almost entirely in the purest of the air before it has reached the men. A remedy for another nuisance is to supply iron trams, with two iron lids on hinges, to each range of work, and place them in the return air after it had left the men. They were generally used in the Standedge Tunnel, of which I was the engineer, and were brought out and emptied once a week. I have never yet met with such a contrivance in any mine, and yet it is evident it would in a short time repay its cost. In estimating the effect of all that I have described in producing disease, it must be recollected that the adult workmen are seldom exposed to their action in the working-places where the concentration is greatest for more than eight hours continuously. Many of them pass occasionally in and out of the working-place at meals and other times, and many of the lads are as much in the air-current (whatever that may be) as in the unventilated ends.

Mr. Ratcliffe's tables give the duration of life of miners at not much under the average of England and Wales, but appended to it is this remark :—

"This class of lives shows a very large amount of average sickness at every period, and increased sickness with advance of years. From the very nature of the employment this must have been anticipated, but not to such an extent as appears from these results. At age 20 miners experience an average sickness of 46 per cent. more than the general class; at age 30 they have 70 per cent.; at 40 years, 78 per cent.; at 50 years, 76 per cent. and at 60 years, 53 per cent. more average sickness than the general class of lives. The aggregate amount of sickness experienced by miners for the period of life, 20—60, is 95 weeks, showing an excess of about 67 per cent. more than the general results. Had these lives, which form 4.93 per cent. of the general class, been first extracted therefrom (and which should have been the case), it would have shown a less amount of average sickness experienced by the general class, and consequently would have proved that miners are subject to more average sickness per annum in excess of the general class than appears to exist."

But these tables do not include lives under eighteen, before which time it will be shown that not only disease, but an excessive mortality occurs.

In Cornwall it has been ascertained that 61 per cent. of the miners die from diseases of the chest—31 per cent. only of the rest of the population.

In the Report on Mines, 1842, it is remarked "the ironstone pits are in general less perfectly ventilated and drained than the coal mines, and are, therefore, still more unhealthy, producing the same physical deterioration, and the same diseases, but in a more intense degree. The ultimate effect of the disadvantageous circumstances under which the miner in tin, copper, lead, and zinc mines is obliged to pursue his laborious occupation, is the production of certain diseases (seated chiefly in the organs of respiration), by which he is rendered incapable of following his work, and by which his existence is terminated at an earlier period than is common in other branches of industry, not excepting even that of the collier. The primary and ever active agent which principally produces this result, is the noxious air of the places in which the work is carried on." A surgeon writes, "In reality what is this number of violent deaths (and I appeal to my fellow-practitioners at collieries) compared with those thousands of persons who advance day by day bowed down to a premature death arising from their occupation, and which brings on an old age, overwhelmed with infirmity, at a period when other men still enjoy the plenitude of their strength?"

It is very much to be desired that tables of mortality should be constructed based upon the numbers given in the last census, which would express in exact figures, not only the comparative unhealthiness of each class of mines, but the mortality caused in each mining locality by the neglect or improper methods of ventilation. In the following table will be found the relative numbers employed at each age, of miners, agricultural labourers, and labourers, in town and country.

OCCUPATION.	All ages.	5 to 10.	10 to 15.	15 to 20.	20 to 25.	25 to 30.	30 to 35.	35 to 40.	40 to 45.	45 to 50.	50 to 55.	55 to 60.	60 to 65.	65 to 70.	70 to 75.	75 to 80.	80 and upwards.	Average age of living.	Age of commencing work.	Age of leaving off work.	Number of years of labour.
Coal miners	1000	5	124	171	169	130	100	94	62	48	36	21	18	10	6	2	1	26·1	11·2	39·7	28·5
Iron miners	1000	5	97	147	194	160	122	92	64	45	31	19	13	7	3	1	—	26·8	13·4	38·8	25·4
Lead miners	1000	3	79	147	167	143	112	94	75	60	46	31	23	12	4	3	1	28·9	12·9	42·5	29·6
Copper miners	1000	10	116	183	156	127	100	82	65	57	43	27	17	10	4	2	1	26·4	11·6	38·9	27·3
Tin miners	1000	12	143	178	150	116	89	79	63	56	41	30	20	11	7	4	1	25·7	10·6	38·2	27·6
Agricultural labourers	1000	6	75	115	113	108	98	88	80	72	67	51	47	32	24	14	10	34·2	11·3	53·6	42·3
Labourers' class undefined	1000	2	39	108	137	124	113	94	90	69	66	44	43	28	22	12	9	34	14·6	50·6	36

I have taken these classes for comparison, inasmuch as mining is usually carried on in agricultural districts, and the wasting ranks of the miners are supplied chiefly from these classes, and I shall hereafter show that the occupation of the miner is not necessarily much more unhealthy. In the four last columns of the table, I have endeavoured, as well as the materials and nature of such a calculation would allow, to present the average ages of the whole of the persons following these occupations in 1851, as well as the age of commencing work, and the average number of years of work done by each class. The differences will be rendered more apparent to the eye, by the diagram on the wall, in which the base line represents years, divided by vertical lines into periods of 5. The heights of the intersection of the curved lines with each vertical line, represent the numbers out of each 1000 workmen at work at those respective ages.

Hence it appears that the average age of miners living, varies from 25·7 years in the case of tin miners, to 28·9 amongst lead miners, being a difference of about 3 years, but this is accounted for by the tin miners commencing work at 10½ years of age, the lead miners not till above 13 years, on the average. These are the extremes of age, within which, on an average, each of the five classes of miners begin work.

The result bears out my previous quotation as to iron mines being the unhealthiest of all, for notwithstanding that the men do not commence work until 13 or 14 years of age, their span of labour only reaches 25·4 years, which is 2¼ years below the average time in which a miner wears out. The miners last but 27·7 years, whilst 42·3 years are got out of the agricultural labourer. In other words, the lives of the miners, in addition to excessive sickness and diminished strength, are shortened by an amount equivalent to more than half their working life.

These tables are to a great degree confirmed by limited observations in particular mining districts. Mr. Robert Blee, in 1847, comparing the agricultural and mining population in Cornwall, gives 52½ as the average age of the former, 42 of the latter; in neither case including any below 10 years of age. Again, of the total number of males dying in ten years, there died per cent. between the ages of

District.	Gross Male Population.	to 10.	10 to 20.	20 to 30.	30 to 40.	40 to 50.	50 to 60.	60 to 70.	70 to 80.	80 to 90
Not Mining.	10322	42·4	4·6	6·9	6·6	6	7·2	9	10·9	6
Mining.	10869	42.8	7	8·4	7·9	9·4	10·6	7	4·7	2·7

Dr. Barham states, "On the whole it may, perhaps, be a fairer deduction from the data hitherto collected as to the comparative longevity of miners, and other labourers, in nearly similar general circumstances in this county (Cornwall), that ten, rather than twenty years,

approximate to the period by which the average life of the miner is shortened by his occupation."

It results from the particulars which I have given that 117 agricultural labourers do as much work in their lives as 174 colliers, as 194 iron miners, 168 lead miners, 183 copper miners, 179 tin miners, or as 137 labourers of the general class.

In tracing out the remedies to be applied to render the cell of the miners a fit place for human beings to pass a large portion of their lives, it is necessary for me to point out that it requires no other remedy, except in a higher degree, than we are now adopting on the surface. The same rules of ventilation, the same habits of cleanliness, will suffice. They have reached their present condition just in the same manner as a portion of any town inhabited by the poor, unvisited by intelligent or professional men, uncared for and never entered by the owners of the property, would infallibly become the stronghold of disease.

Many of the proprietors and managers, I find, have never realised the fact of their workmen being short-lived, and are equally unconscious or forgetful of three-quarters of the accidents which occur in their mines. There are exceptions, and examples every way worthy of imitation, to which I shall hereafter allude, but truth compels me to state that, in the vast majority of mines in this country, such is the want of education amongst the class from which the managers are chosen, that persuasion, backed by the strongest facts, is of no avail in inducing them to adopt inexpensive measures to improve the sanitary condition of their mines, or to prevent accidents in them. Any one who has been engaged in the removal of nuisances will readily appreciate the difficulty in influencing the despots who rule an unknown land. In my endeavours towards this object, I have always done, as I shall do in this paper: I have scrupulously avoided any recommendation attended with a considerable outlay, or in which the care and expense would not be amply repaid. I have invariably found that those mines which were worked most economically, and with a large production, were the most healthy and the safest. The same intelligence which effects the one, carries out the other as an inseparable condition. In fire-damp mines, the ventilation is generally better than in others, and several persons are employed in attending to the airways and ventilation. On dividing the quantity of coal brought out, by the whole number of men employed in a large number of fire-damp mines, including those employed in ventilation, and also in a large number of those not containing fire-damp, I found in the former that each man did considerably more work. Miners themselves, until the candles burn dimly, are so little conscious of the effects of imperfect ventilation, that they commonly object to improvement, and yet they have admitted to me, after it had had a sufficient trial, that they could do one-fourth more work. There are many mines, or parts of mines, which can hardly be worked in the summer, because candles will not burn. The ventilation entirely stagnates in the act of reversing. The powder-smoke hangs in the face so as to cause a delay of half an hour after each shot is fired, and the workman will have to stop after every dozen strokes with his pick to trim his light. Such are a few of the conditions which, occurring frequently amongst a large number of men in mines where no artificial means of ventilation are employed, produce losses on a large scale, but which, as they are customary, are seldom appreciated by the proprietors. In suggesting these things to them, before entering a mine, although it may be difficult for them to tell me which way the air goes in, I am met with a blank denial; and yet, on entering, the state of the extremities they are obliged to admit, and is exactly as any experienced man would have foretold. It has been remarked that evidence has been given at every inquest, on the most serious explosions of fire-damp, that the ventilation of the mine was good. In metalliferous mines, the good ventilation I found sometimes to be, in the adit or water level, most ignorantly left open, which effectually cuts off the ventilation from the lower parts of the mine.

I have already shown that one-third of the value of the miner was cut off by the hand of death; but the causes which have brought him to the tomb must have necessarily diminished the amount of work he is able to perform, even in the best years of life; and during $\frac{1}{15}$th of his working-life he depends on the sick-club or parish for support. He has good grounds, therefore, for receiving a high rate of wages, and he is especially in need of the assistance of benefit societies to help him in this period of trial.

"As an evidence of the good economy of spending money to lessen these terrible effects of the miners' occupation," Mr. Blee states, "that, from a return made by the relieving officer of Gwennap to the Redruth Board of Guardians, he has ascertained that of 240 families receiving parochial relief in Gwennap, in one quarter of last year, upwards of 200 were miners' families; and that, of the fathers of those families, fifteen had been killed in the mines; forty had been blinded, maimed, or so injured otherwise by mine accidents, as to be unable longer to earn a livelihood, many of the injuries, at different distances of time, having terminated fatally, while sixty-five have died, and fifteen others, who had among them eighty children, were dying more or less slowly of miners' consumption." I might add many facts to illustrate how important it is to the pockets of mine-owners to keep their miners in at least as good condition as their horses, and to exercise that degree of superintendence over them in the regions of darkness, which it would be considered ruinous to neglect if the same men were working at the surface. The benefit and check of piece-work underground is very often lost.

The age fixed by the legislature, as the earliest at which boys may be employed underground is often evaded, as the census returns show. It is not always the fault of the manager that they are brought in, as the parents sometimes represent them to be older then they are. A register of birth should be required with each. From the numbers which I have given in a previous table, it may readily be shown that but a small number of boys enter the mines between 10 and 12 years of age, (in some lead mines of Cumberland they are not taken under 18,) and, therefore, that there would be a small apparent sacrifice if the proprietors were to yield to the petition of the coal miners of the north of England, that no boy should enter the mines until 12 years of age, in order that he may have time for education. The proportion of the boys so excluded, who would go off into other employments, would be insignificant, and the gain, intelligence, and strength of constitution of the others would doubtless amply compensate it. One of the most important duties in fire-damp mines, is entrusted often to the youngest of the boys, that of opening the ventilating doors to allow trams to pass. Who has not heard of and sympathised with these children, taken from their amusements and the education of daylight and confined in darkness and solitude; and yet, often in their forgetfulness, the door is left open, a number of men are deprived of the proper amount of oxygen, and in fire-damp mines where locked safety-lamps are not used, a few minutes may suffice for an explosion, which indeed has been too often the result. The doors should be always so hung as to close to of their own accord, after a tram has passed.

In entering upon the all-important subject of ventilation, I have little fear but that most mining engineers will subscribe with me to the correctness of the report of 1842, "That a mine when properly ventilated and drained, and when both the main and the side passages are of tolerable height, is not only not unhealthy, but the temperature being moderate and very uniform it is considered, as a place of work, more salubrious and even agreeable than that in which many kinds of labour are carried on above ground."

To effect this, requires one simple regulation to be unremittingly carried out, namely—that no man shall work in a stagnant atmosphere, that the working places as now existing, the reservoirs of all the deleterious gases brought along by the air current, shall have a current sent through them into every part in sufficient quantity to dilute all the deleterious gases and deprive them of their power, or, in the words of the resolution passed by a meeting of deputies from the coal-mining interests of the kingdom, in May, 1854—"That adequate artificial means of ventilation be provided at all collieries, and that there shall be at all times a sufficient current of pure air through the workings to dilute and render innocuous all noxious and deleterious gases." Mr. Richardson estimates that the quantity of air required for vital chemical purposes should be per hour—

For breathing	14·0	cub. ft. per man per hour.
For displacing carbonic acid	62·8	do.
For diluting nitrogen	258·4	do.
For displacing perspiration	97·0	do.
	432·2	
For the combustion of one light	59·3	cubic feet.
For one-fifth of that needed for a horse.....	517·0	
	1008·5	

This agrees nearly with the estimate of Dr. Hutchinson, but it does not quite provide for diluting the gases to a point where they would be no longer injurious, nor for removing the air after it has been breathed, especially when a number of men are working at a continuous face of rock. The slow diffusion of the gases must also be considered, and the variety of impurities, and that hard work is going on in a room of the lowest possible height.

Mr. T. J. Taylor, in answer to Question 6019, before the Committee of the House of Lords on Local Mines—"What would be the least amount of current with which you would be satisfied in any of those pits which you have under your management?"—"That would depend on the requirements of the mine; for example, in a mine which yields no fire-damp, with 120 or 130 persons employed in it, I should say that a current of 20,000 to 30,000 cubic feet per minute might be a fair quantity, being properly conveyed up to the face of the workings, and made to sweep those districts where the people are employed; but in a fiery mine I should require very much more than the quantity named."

After having examined and measured the ventilation in a great number of mines I have found the simple rule hold good, that where there was no escape of fire-damp, and little of any other mineral gas, that 100 cubic feet of air per man or boy per minute, was the minimum quantity of air essential for sanitary purposes alone.

This quantity of air it is quite impossible to introduce with air pipes in the manner recommended by many benevolent persons not practically acquainted with mines, but it can be introduced and passed round by means of the opening which the miner is obliged to make to work forward himself and extract his minerals. The employment of small faces and narrow air tubes, or of the waterfalls used in the Cornish winzes, are radical errors; they are contrivances for enabling a man to breathe over and over again the same air, and to accumulate nuisances, and they cannot be too soon discarded.

The miner is now obliged to bring the current of air perhaps several miles, to within 20 or 100 yards, in order to keep his candle burning; this, then, is the only further distance that the air has to be carried. It can be carried by the same means by which it has already travelled so far, viz., by a double air course, one serving for the incoming air, the other for the outgoing, with communications from one to the other at intervals. Temporary brattices or partitions are needed, of the kinds shown in the drawing on the wall, to complete these communications. The means already exist at every mine for the purpose, except a few planks or tarred canvass sheets to form the moveable brattice.

The main current of air can be increased to the required amount, if tolerable attention be paid to the airways, to keep those well open which have been constructed, and a simple artificial means of ventilation be applied at the shafts.

Judicious splitting or dividing the currents of air will bring almost any quantity of air through the mine. It is the same thing as having a number of pipes to take water from one reservoir to another in lieu of one. In the Hetton colliery, such is the skilful management of these splits, that by means of natural temperature alone, on a winter's day, it has been found that as much air goes through the workings, (100,000 cubic feet per minute) as can be obtained at some other large mines by the use of immense furnaces.

By having a separate split, or current of air to ventilate each range of workings, the air will be brought much cooler and purer to the miners;—it is the great modern improvement in the ventilation of mines. The cost of the ventilating power in the most difficult mines, and where there is the largest escape of gas, does not exceed a penny per man per day; in mines where there is little or no escape of inflammable gas, the expense would not be half so great. This is the cost when a furnace is used at the bottom of the up-cast shaft to rarify the air. Few persons who have tried the experiment will deny that in previously badly-ventilated mines, the consumption of one ton of coal per day, at the bottom of an up-cast shaft, with proper attention to the airways, will enable each collier to cut one ton of coals more per day with the same amount of exertion. In well-constructed furnaces, a consumption of one ton of coal per day will raise 60,000 cubic feet of air per minute 30° in temperature, a temperature amply sufficient to produce the motive power necessary for ventilation, at the worst periods of the year, in all mines not containing fire-damp. It has been shown in Belgium, where about 200 of the most dangerous mines are provided with ventilating machines, that they produce the largest amount of air required in those difficult mines with about half as great a consumption of fuel as the furnace previously employed. Models of some of the best of these ventilators are on the table. The fan of Mr. Lloyd, of Great Guildford-street, described in the Jury Report of the Great Exhibition of 1851, gives the best effect of the quick-motion machines, but when the drag of a mine, or resistance to the passage of air exceeds half an inch of water, the machines of Mr. Struvé, Mr. George Jones, of Birmingham, of Messrs. Fabry and Lemielle, give a much more economical result. Ventilating by a furnace is most suitable to coal mines, where the fuel is close at hand, but even in these, when the upcast shafts are shallow, or contracted, divided by brattices, used for pumping, or are very wet, or not walled, the superiority of ventilators is still more striking than I have named. The sweeping objections made to all mechanical contrivances for this purpose, on the ground that they are liable to break down inside, by those who think that only the system they have seen carried out is the best, are inconsistent with the practical experience of nearly twenty years in Belgium. My limits will not allow me to enter on an investigation of the principles of ventilation, but it will be useful to point out some of the errors to which deficient ventilation in mining are attributable.

One almost universal neglect in such cases is allowing the air to leak from the in-coming air-current into the out-going; thus, a crack, one-eighth of an inch wide, on each side of a brattice in a shaft 200 yards deep, will cut off most of the air. Air always tends to take the shortest course. The channel leading the air from the surface to the miners should be made as air-tight as possible. I have known men unable to enter parts of a mine for

weeks, in consequence of the state of the ventilation, until some one suggested that the stoppings should be looked to and made tight. After the air has passed the men and become rarified, it cannot be taken downwards without a loss of power.

In deep metalliferous mines, a natural ventilating power, equivalent to nearly fifteen horses, is sometimes entirely sacrificed. The air-ways should be as nearly of the same size as possible; and common sense ought to show that the largeness of the air-way is useless if obstructions are allowed to exist. Yet it is to these very obstructions that I am sometimes taken by miners, to show me what a good ventilation there must be when the air will nearly blow out a candle in going through a small hole.

The following are the simplified results which I have deduced from a large number of experiments in every kind of mine:—

1. The quantity of air which passes through air-ways of equal length is in proportion to their areas multipled by the square root of their respective diameters.

2. When the areas are similar, and the lengths unequal, but great in proportion to the depth of the shaft, the quantities of air are inversely as the square roots of the lengths of the air-ways.

3. The quantities of air passing through mines are in proportion (other conditions being similar) to the square root of the depth of the shaft, or of the height of the column of air rarified by natural or artificial causes.

4. The amount of ventilation passing through a mine is in proportion to the square root of the difference of the temperatures of the downcast and upcast shafts.

5. The resistance to the passage of the air through the mine or any air-way increases as the square of the velocity.

6. The power required to ventilate a mine increases in a higher ratio than the cube of the amount of ventilation, *i.e.*, to double the ventilation requires at least eight times the power, but if two currents of air are made in the mine instead of one, the power required is little more than double. This demonstrates the economy of "splitting."

7. Air should, as a rule, not travel underground at a greater velocity than five lineal feet in a second. The most fiery mines in England have not an average of three feet per second sweeping the working faces. If the velocity in the airways exceeds five feet, the loss by leakage, and the power expended in ventilation, increase in a high ratio.

8. Air should never flow in any part of any mine at a less rate than half a foot in a second. This is not sufficient to deflect perceptibly the flame of a candle.

9. No single current of air should ever supply more than 50 men and 5 horses.

10. No airway of a mine should be so small that a man cannot walk easily through and bring in a tram to repair it.

11. In furnace ventilation, one square foot of area in a deep upcast shaft should be allowed for every 1,000 cubic feet of ventilation per minute. For mechanical ventilation a less area will suffice, although it increases the power required.

12. To ascertain the minimum amount of ventilation required for sanitary purposes in any mine which contains no explosive gas, and little mineral gas, multiply the number of men and boys employed underground by 100, the number of horses by 500, and the product will be the number of cubic feet of air per minute.

From the evidence given by Mr. Woodhouse, of Overseal, mining overseer of the Moira Collieries, who has had great experience in the scientific ventilation of coal mines, it appears that a large saving of expense is invariably realised in practice from the adoption of the improved modes of ventilation, because the constant introduction of fresh currents of atmospheric air into the pits, tends in a remarkable degree to protect the wood work of the mine, and to keep the roadways dry and in good order. After speaking of the drawbacks from the profits of collieries arising from an imperfect system of ventilation—imperfect as regards the whole quantity of air passed through the workings, but still more imperfect in its distribution, he says,—"The improved system adopted in the collieries on the Tyne and the Wear, of dividing the workings into districts, and so obtaining a current of fresh air in every division, may in many cases be adopted at a trifling expense in these counties; and although the extent of the workings in general bears no porportion to those in the colleries in the north, the principle remains the same, and the result would be favourable in a corresponding degree. It may be urged that the immense quantity of gas given out of the coal in the north has called for the improved system there, which is probably the fact; but there are many advantages to be derived from good ventilation beyond the mere prevention of explosion. In pits with a rapid circulation, the men respire more freely, the road ways are kept dry and repaired at less expense, and the timber lasts longer *by years*, and, therefore, it is a matter of strict economy to ensure a good ventilation. The men suffer most materially from working in an impure atmosphere. In some mines the air can scarcely be perceived to move at all, a thick mist or fog pervading the whole pit; which is caused partly by fermentation in the wastes and old works, partly by the lights, and partly by the heat and effluvia from the horses and men. This, with a large proportion of carbonic acid gas, forms an atmosphere that none but colliers who are accustomed to it could endure, but which has the effect of shortening their days."

The saving of timber from improved ventilation is estimated even as high as 80 per cent. The proprietor of a colliery informs me that he has just reduced the expense of timber in the first year of trial from 6d. to 4½d. on the ton of coal extracted.

One of the consequences of bad ventilation is, that it induces the inclination to indulge in strong drinks after coming out of the mine. Some medical men have even asserted that a small quantity of spirits was beneficial; but there is no doubt that in a few of the mining districts of England, it prevails to a great extent, causing a considerable loss of time after each payment of wages, and rendering accidents more frequent on the first day after commencing work. Considering all the circumstances of the life of the miner, his arduous struggle for life, his early death, his privation from the lessons of nature and of surface life, he seems in a peculiar degree entitled to the sympathies and philanthropic exertions, if not duties, of his employer. This feeling is becoming more awakened, and very much is due to the exertions of Mr. Tremenheere, but it is lamentable to think how small is the number in whom even the necessaries or the education of the miner excite a more than passing care. I regret often to observe more care exhibited to provide for the health or the safety of the horses. It is looked upon as an extraordinary example of generosity to insure the lives of some of the miners for £10 a-head. Of the condition of miners at the surface, and the state of their dwellings, it will not be necessary for me to treat in these illustrations of under-ground life. In these respects, however, as well as in most others which relate to the well-being of the miner, I cannot but cite as examples of excellence the works of Anzin, Grand Hornu, Mariemont, and others, in the coalfield stretching from Valenciennes to Aix-la-Chapelle; and I hope that proprietors of mines in this country may be tempted to go and see, with their own eyes, how much is done by every mining proprietor, and the largest mining companies, of their own free-will. Some particulars are given in the Report of Mr. Tremenheere.

Mines in this neighbourhood are remarked at a distance by enormous buildings, which enclose the machinery and the top of the pit, and the persons at work on the surface. In it are rooms for dressing and undressing, washing, drying clothes, as well as the necessary offices. There can be no question of the influence which those habits of

cleanliness, and a change of clothes to walk home in, have on the health of the miner.

As long back as 1826, the Anzin Company erected bathing halls for the miners, supplied with waste hot water from the pumping engines. The system is one which could be adopted at a small outlay at every mine where a pumping engine is in use, and convert to a philanthropic and remunerative use, heat which is now run to waste. Mr. Lanyon says, "A well constructed changing house, containing a warm bath, should be deemed indispensable at every mine." Lady Bassett's philanthropic exertions in Cornwall in effecting these objects deserve especial mention.

At several mines on the Continent, I found barracks fitted up for those men who came from a distance, and who only returned home once a week, thereby avoiding the risk of cold from the chill which ensues after leaving a deep unventilated mine on a cold day.

Another regulation, very common at continental mines, is the providing an accident room, in which are kept the most necessary remedies for sudden cases of illness or accidents, and simple couches, stretchers, or apparatus for producing artificial respiration. The list of apparatus and remedies necessary, can be easily supplied by the surgeon connected with the works who should be required to visit this room at least once a week. It is intended that whenever a casualty occurs he should be immediately sent for, but that in the meantime the managers of the work should apply, as far as their printed directions extend, the preliminary measures for alleviating or restoring the sufferers. I have no doubt that many lives might be saved after explosions of fire-damp in England, if such a system were pursued. Fractures are often rendered more serious from the distance the men have to be carried, the want of a proper stretcher, and the ignorance of those removing the patient. A model on the table, one of several which I have been preparing for the Pathological Exhibition of the Society, represents a mattrass, or thick coverlid, of water-proof material, mounted on a plank or light frame, which may be kept in the bottom of the mine. The patient being placed in an easy posture and tied in with straw or hay as packing, if any is at hand, is brought out without having to alter his position, and he may be raised up the shaft in a vertical position, the limb remaining in the best position for subsequent surgical operations. Vandenbroeck states that after the battle of Waterloo a large number of the wounded presented themselves with well-executed arterial compressions, to which they owed their lives. They assured him that in each of their companies some of their fellow soldiers had learned this easy operation.

Very much may be done in this and similar directions which will suggest themselves to the medical attendant at each colliery, and as they are very generally paid 1d. or 2d. a week by each man, there seems no difficulty, beyond that of inducing some one to set the example, why a practice so general and highly spoken of by colliery practitioners on the continent, should not become general in this country.

Humboldt, in a work published in 1798, describes some ingenious lamps, supplied with common air, which would burn for some time without the contained supply being replenished. As the light burnt dimly, the air was let in from the reservoir.

It cannot be denied that the production of coal and minerals in this country is far greater than that of any other continental country. In the former mineral, it is threefold as much as that of the three next largest coal-producing countries of the Continent united. We have mines carried on on a scale with which none on the Continent can compare; and it would be difficult, in the present state of our knowledge, to point out how the ventilation of some of our great northern mines could be in principle improved; but unfortunately there results from this, and the very excess of one of our Anglo-Saxon qualities, that we are too apt to think ourselves in every way superior, and that we have nothing to learn. In nothing are we more behind them than in the pathology of miners. It does actually happen that in proportion to the resources of the raw material, coal, we produce less than France and Belgium in the proportion to one acre of surface of somewhere about 10, 17½, and 15 tons. This has an important bearing on the difficulty of working mines, and the position of the collier. Already, with the large portion of the population devoted to mining, the rapidity with which they die out, the increase of demand for minerals, and the difficulty of finding workmen, the question is beginning to press—from whence are the labourers to come? A migrating tide of colliers in pursuit of higher wages is flowing from west to east in the coalfields of South Wales. The accumulation of colliery population to certain centres increases the difficulty of finding recruits; and whether the nation at large or our manufacturers are to pay a higher price for our minerals or not the pathology of miners will assume every day a position of more vital importance to the owners of mining property.

The Cornwall Polytechnic Society, whose members are to a great extent connected with mines, have paid constant attention to these questions, and spent large sums in premiums for improvements in the condition of the miner. They have just issued an announcement of premiums of £40 and £20 for the two best ventilated mines, and of £10 and £5 for the best model and plan of ventilating ends.

To sum up my recommendation for the sanitary improvements of mines, they are—

1. That an artificial power and other means of ventilation, under the constant superintendence of appointed persons, should be employed at every mine, so as to produce at all times a regular current of pure air into and throughout the whole of the working places and parts of a mine past every workman, and so as to dilute and render imperceptible and harmless all noxious gases at the points where they are given off. That the velocity and abundance of the current of air, which must be easily accessible for examination and repairs at all points, should be regulated to the extent of the works, the number of workmen, and the escape or formation of gases and other nuisances.

2. That dung-heaps, putrescent timber, and similar nuisances should be removed from the mine at least once a month, and the exhalations at all times carefully prevented from mixing with the incoming air.

3. That a medical officer should examine the sanitary state of the mine at least twice a year, and report thereon to the owners and to the government.

4. That there should be an accident-room at every work, provided with necessaries, and inspected once a week by the medical officer.

5. That a benefit society should be established at every mine, at the joint expense, and under the joint management of the proprietors and workmen, to provide medical attendance for the workmen and their families, to support them when sick or wounded, and to pension them off when too old or maimed to gain a livelihood.

I was, I confess, once sanguine enough to suppose that persuasion and argument would be sufficient to induce most persons to adopt plans which, in other places, had been found, under similar circumstances, remunerative. My present conviction is, that however indefatigably such exertions may be pursued, if we trust to those alone, the present race of miners will be swept from the earth before any one of these recommendations is adopted in one-quarter of the mines of this country. The loss of life which I have pointed out, no one can say is attributable to the recklessness of the miners; in their petitions they show a just appreciation of the incubus which rests upon their progress.

These vital improvements and the power of saving life to an extent not difficult to calculate, rest upon the masters, and on them alone. I think I have shown satisfactorily, by the proofs of some amongst them, and of other persons rather than my own, that it is not against their interests,

moral or pecuniary, to set about the work. If the necessity of some sanitary measure is the first step to legislation, then certainly the mines are the first places where it should begin. It is painful to be compelled to form so low an estimate of this division of pathological progress, or to give the palm in any respect to other nations, but we have to perform a duty to future generations as well as to our own, and we shall do more good and show more true love to our country by looking into our deficiencies than counting up our triumphs.

DISCUSSION.

The CHAIRMAN said, according to the usual practice, they would now enter into a discussion upon Mr. Mackworth's paper. He would remark that it went straight to the point which the Industrial Pathology Committee appointed by the Council of the Society of Arts had made the chief question of their investigation, which was this:—Was it necessary that certain positions of the human body, known to be prejudicial to health, in various departments of mechanical labour, should be continued to be practised, or was it not? and was it possible that, in a great labouring country like England, people should work and not be deteriorated in their physical condition by that work, or was it not possible? As far as the investigations of the Committee had as yet gone, the evidence tended to show that it was not impossible; and that the great evils, in almost all industrial occupations, arose from defective ventilation—from a culpable disregard of established principles with regard to the health and comfort of the operatives—from insufficient drainage, and—from awkward positions in the performance of the manual operations. The inference drawn by the Committee up to the present time, was, that most occupations might be rendered more healthy by an avoidance of these evils. Mr. Mackworth's paper went very far to confirm this view, and that gentleman stated, as the result of considerable experience on the subject, that the diseases incidental to miners arose, in a great degree, from ignorance of proper methods of ventilation and mismanagement, which might be remedied at a cost which would not interfere with the profits of the coal-owner. That was a point which was deserving of investigation, and it was upon that he hoped to hear some remarks in the course of this discussion. It was unnecessary to say how very important this subject was, affecting, as it did, more than 300,000 of the population. These men were working, like moles, in the earth, and they became mole-like in their habits and manners. He remembered being very much struck by what he once heard from a coal-owner in Yorkshire. From some cause or other the coal-owner had been obliged to bring some of his men before the magistrates, by whom they were sentenced to a term of imprisonment in Wakefield gaol, with hard labour. The complaint of the men was, not that they had to work, but that they were compelled to keep themselves in the ordinary posture of rational creatures.

Mr. CHADWICK begged leave to express his satisfaction with the paper which had been just read, and at the course of investigation adopted by the Society into what had been called Industrial Pathology, or, in the vernacular, health of manufacturing processes, of which investigations this paper might serve as an example. The course of investigation into the health of manufactures might be undertaken legitimately, simply and solely for the improvement of art, because, according to his observation, there was scarcely any sanitary evil arising in the conduct of arts or manufactures which did not, on examination, appear to arise from some rude and imperfect condition or process, capable of removal by some corresponding and substantial improvement in art; and there was rarely any substantial improvement in art or manufactures which was not attended by an economy, or an improvement in the object of the pursuit—the pecuniary result. So commonly had this been the case as to warrant the declaration, that they might, for the purposes of such investigations, relieve their minds from the immediate or passing consideration of the excessive sickness, the mutilations, the horrible deaths, the orphanage and widowhood, the premature and wretched disability, and keep their own and manufacturers' views in eventual "paying" results. Early in his sanitary investigations, an instance had been brought under his notice of this kind, in the conduct of the mining art. The late Lady Basset was the benevolent owner of the Dolcoath mine, at Camborne, in Cornwall. She felt for the sufferings of the miners, for their exhausting labour in ascending and descending the pits, the bad condition of the atmosphere in which they worked, and their sufferings under the severity of the change of condition when they came out of the mines in winter, exposed to wet and cold, engendering rheumatic pains. For their relief she consulted an enlightened physician—Dr. Carlyon—enlightened in prevention. The pains and exhaustion of the ascent and descent were relieved by machinery, ventilating appliances abated the evils of the atmosphere in the mine, and when the men ascended in the afternoon, instead of issuing on the blank hill side and receiving beer in a cold shed, they issued from their underground labour into a warm room, where well-dried clothes were ready for them, and warm water and baths (from the waste water of the steam furnace); and instead of beer a provision of good soup was made for them. It was proved to him (Mr. Chadwick) in a report from Dr. Barham, that by a combination of well devised benevolent arrangements, the health of that mining population was brought up to the health of the adjacent agricultural labourers working on the surface. But it appeared that Dr. Carlyon might have been consulted not as a physician, but as a mining manager. It turned out that steam power was far cheaper than the human power heretofore exhausted in the deep descent and in the ascent. With the saved strength the men did more work in the relieved atmosphere beneath; the skilled and mature workmen were not so frequently swept away by permature disablement or mortality; they were, from less discomfort, less untrustworthy, and they worked more steadily. The principle adverted to was vindicated, and it was proved that good sanitary provisions were sound economical provisions; and that benevolent works paid as investments of capital. Such examples it would be the duty of a zealous and competent inspection on behalf of the public to propagate. But it was proper to state that, under existing circumstances, much of the interest in improvements, or in acting on proved suggestions, was frequently shifted and dissipated and lost. Adventurers opened mines in rural parishes; they subjected the districts to nuisances created by rude and imperfect processes, as from smoke, by the wasteful consumption of fuel; by ignorant processes and the reckless direction of labour, they wasted valuable life, and shifted from themselves on to the poor-rates, and on the surrounding ratepayers, the pecuniary consequences of disablement and widowhood, which consequence the adventurers had, and the ratepayers had not, the means of preventing. When serving on the Central Commission for Enquiring into the Labour in Factories, great numbers of dreadful accidents and mutilations, the consequences of rude processes, were brought before them. The first question raised upon them was, whether they should recommend government inspectors to be armed with arbitrary powers of ordering the adoption of works and means of prevention. To himself and his colleagues, it appeared to be the most expedient to have recourse to the principle of concentrating responsibility where there was the best means of prevention,—namely, in the owner or the user of the machinery. But the adoption of this principle of unity of responsibility, was prevented by the adverse interests to the public, which were wont to influence the House of Commons on such questions. It was alleged that the prevention of such accidents was impossible. Adopting this declaration, assuming that the processes were the perfection of art, and the casualties en-

tirely blameless, why should the necessary and proper consequences of these processes be borne by ratepayers and others, (at all events in such excess) where they had nothing to do with them, and derived no benefit from them? He still contended that those full and assumed unavoidable consequences should be imposed on the processes themselves, as an insurance charge. As an insurance charge—supposing the imposition general, as it should be—it would be properly borne by the consumer, and he who derived the benefit from the process would pay for it, as he ought to do, in an increase of price compensating for the whole expense of the commodity. But this imposition of the insurance charge upon the consumer would have the benefit, in creating a proportionate bounty on improvements to the adventurers or directors of the art processes, in all the savings effected by them. Under such a bounty, inventions, and the adoption of inventions, would receive a high stimulus, reaching the rudest minds. Instead of a deaf ear being turned to such official scouts for consequences as the author of the paper read before them, he would be frequently received as the welcome harbinger of profit. Luckily for the public who travelled by railways the principle in question had been partially adopted in Lord Campbell's Act, which rendered the users of machinery responsible for the pecuniary consequences of the loss of life, as well as of limb, inflicted from *culpable* remissness. The interposition of the element and question of culpability was a large legislative and economical error. It should be assumed that the accidents were all unavoidable, and the charge of the whole consequences should be imposed simply as an insurance charge. Luckily for the public and the future improvements in arts, and the future saving of the pain which money could not compensate, there was rarely any serious accidents where some gross and culpable mismanagement, some rudeness or imperfection capable of future prevention could not be maintained in evidence. When heavy cases of compensation did occur, if they watched their operation in the minds of railway directors, they would see the becoming concern with which the accidents were regarded, and not summarily dismissed, but looked to with solicitude, with the view to the competency for the agency for future prevention. Though the principle in question was as yet but partially applied, and admitted of much improvement, when examined it would be found to have greatly diminished the hazards of those tremendously dangerous machines, the locomotives, and increased the safety of railway travelling. But in France the principle of concentrated responsibility contended for had been adopted. The code rendered all users of machinery or processes liable in civil damages for the consequences of whatever accidents or injuries resulted from their use. The French code was in operation in Belgium. In the superior intelligence of the direction of the mining labour in France and Belgium, in the more ready adoption of improvements, in the greater productiveness of the working of the mines—to which the most important portions of the paper read that evening testified, might be seen the probably unconscious operation of the principles of the concentration of responsibility where there was the best means of preventing them. Neither he nor his colleagues had ever conceived that the principle could or ought to supersede official inspection. Much as his manufacturing friends had grumbled at that inspection, as an imposition and a tyranny, the most candid of the cotton manufacturers at the least, who remembered the general state of the manufactures twenty years ago, when at the recommendation of the central board of engineers, it was imposed, and what was the state of the manufactures now, where there was at least twenty model mills for one that had existed formerly; and that in all these instances, the relation of labourer and employer had improved, and the violent risks of manufactures had diminished, acknowledged the improvement effected by keeping attention sustained to the whole condition of the labourer, and therewith to the processes and the art. It was incredible almost to find in the isolated conduct of manufacturers, in what ignorance the directors were of improvements in labour in successful operation elsewhere, whilst a concentrated responsibility from the imposition of the consequences of accidents or defaults would augment the interest in all improvements in the arts by which they were to be prevented. The duty of inspection, if competently and zealously performed, as it appeared to be in the present instance, might be made the means of at once communicating and explaining to all, the results of whatever new processes were tried.

Mr. Conybeare said, although he had for a long time been a member of this Society, yet he had as yet never attended the meetings, or taken any part in the discussions, but from the interest which he had felt in this subject he had determined upon hearing this paper. He regretted that, in consequence of his late arrival, he had not heard the early portion of the paper, which probably might have dwelt more on Cornish mines, as the latter portion of the paper did on collieries. He should have felt particularly interested in that part of it, if any, which alluded to the diseases incidental to the operatives in the Cornish mines, as distinguished from collieries. He agreed with the author in his general remarks with regard to the collieries, but as to the special diseases of copper miners, he thought they were to be attributed very much to other causes than insufficiency of ventilation. As to ventilation he was struck with the remark of the author as to the desirability of preventing any intercommunications between the outgoing and incoming currents of air; that was opposed to the law of ventilation in the human frame—and as the allowing of those channels of air to come in communication with each other, in consequence of congenital disease, was the cause of the disease called the *blue* disease, so intercommunication, by winzes or otherwise, between the incoming and outgoing channels of air, produced as surely, though not as palpably, a speedy and very similar disease among underground miners. In either case the blood was not sufficiently oxygenated. In the one case, that of the baby, because nature forgot at birth to stop up the antenatal passages connecting the pulmonary artery with the aorta, and the communication between the two auricles; in the other, that of the miner, because, owing to bad engineering, the oxygen of the air in the working parts of the mines became comparatively exhausted, and fresh air, with its fresh supplies of oxygen, was allowed to leak back into the *back* channels without ever reaching the ends, and restoring that due per centage of oxygen to the air inspired by the miner, which was accurately fixed in nature, and necessary for health. But the difficulty of working copper, tin, and lead mines without injury to the health of the miner arose from the fact that the mineral they wanted to work did not lie, as in coal mines, in horizontal strata, but in vertical *lodes*. It was, therefore, much more difficult to define at what exact spots the shafts should be sunk to meet the productive ground, and they had to go to an enormous depth—in some instances 840 fathoms—following the mineral when they had once got at it. He believed it was a false notion of economy with regard to the Cornish mines, in compelling the miners to traverse those enormous depths by means of ladders. No human being could perform such an operation without great injury to health. They would often see the strongest and most robust men, if *not used to such work*, break out into a profuse perspiration from the great physical exertion required in ascending. It was this terrific exertion, equal to walking to the top of Caeder Idris every morning before commencing work, which, in his opinion caused the fatal disease known in Cornwall as the "miner's consumption," which, though the name might lead to a different opinion, was a complaint not of the lungs, but of the heart—the organ overworked in those ladder ascents. He protested against the remark that such questions were

to be dealt with as questions of pounds, shillings and pence, for he contended that it ought to be dealt with on far higher grounds.

Mr. CHADWICK—I said I think it would set us right in these cases.

Mr. CONYBEARE thought not. Look at the like case of the owner of a young horse; many people acted upon the notion that they got more profit out of a horse by beginning to work it at two or three years old, before the back of the animal was properly set for labour; for his own part he believed the average period of hard-working equine life would be 17 or 18 years instead of 9 or 10 years, if they were not put to work at so early an age, before the frame of the animal was set, so as to enable it to endure severe labour. Something of this sort applied to mining labour. They were told that miners in general lived only about half the average of human life, but that was a matter that did not give much concern to the mine owner, inasmuch as when one set of workmen died off, there was a fresh supply of labour to meet the case. Hence the great anxiety observable among Cornish miners to marry early, and have families of boys. Although labour might be regarded as the capital of the labourer, it was a capital he threw away recklessly. It was a question, therefore, for the legislature to look into as regarded the pounds, shillings, and pence part of the case, for such waste of life and sickness was a loss and charge to the country at large, although not to the individual employers of mining labour. There were some things in which they ought not to allow life to be improperly sacrificed. He looked upon it as a moral question, and the great ultimate remedy for the evils complained of would be found in the proper education of the men; meanwhile he would not allow any miner to be worked below a certain depth without man engines to lower and raise the men. The pounds, shillings, and pence view of the question might be true, if they took the community at large, he repeated, but not as applied to the individual employers. There were some descriptions of trade in which it paid the masters to employ workmen at high rates of wages, with a perfect recklessness of the consequences to the life and health of the labourers—for instance, in the phosphorous match business, they sometimes, he believed, employed girls of tender age, and the nature of the occupation was such, that it destroyed health and engendered the most fearful diseases throughout a miserable though shortened existence, without any pecuniary loss accruing to the individual who employed them with an utter recklessness of the consequences to human life and health. With regard to the remark of the Chairman as to the complaint of certain miners that they were compelled, while in jail, to maintain an erect position, the blame was not with the men themselves, that they had a distaste to what had been termed the *distinctive* attitude of human beings. We should say that it was the necessary consequence of the standing muscles not having been properly developed by exercise, and we had no right to blame the miner for not wishing to stand up right, when from the nature of his occupation, he was compelled to adapt himself to unnatural and distorted postures of the body. It was very remarkable that with the generally intelligent and frequently fairly educated class of men composing the body of the Cornish miners, more attention had not been awakened upon these matters which affect their comfort and well-being in life. It was strange that they (who could so well calculate their chances on a "tribute pitch,") should not also calculate their chances of life in their occupations. With respect to Lord Campbell's Act that did not apply to the chief evils among miners. It gave a remedy in cases of *accidents*, but not in cases of loss of health and *chronic diseases*. He believed the great ultimate remedy of the existing evils in the mining occupation would be found in the proper education of the miners; so that they might be brought to regard their true interests as human beings, and to stand upright socially and morally, even while they might be physically incapacitated from retaining that position without great fatigue; the fact being, that standing upright was not, as commonly supposed, a state of rest, but required the combined action of various muscles; and if those were allowed to relax, the upright position would not be for a moment retained, and could only be retained with *great fatigue* by men who, from working chiefly in recumbent attitudes, had not got the muscles of standing in such vigour as would suit a peripatetic philosopher.

Sir JOHN RENNIE said it was a question with him whether governmental interference would work out a remedy for the evils complained of with regard to operations in mines. He thought Government interference would effect very little good in the matter, and he should prefer that the owners of mines should be led to carry out improvements that were brought before their notice, from a conviction of their desirableness and utility, rather than by any strong legislative enactments.

Mr. TENNANT considered it would be an advantage to all parties concerned in mining operations, for the Government to enforce those rules and regulations somewhat similar to other European countries, where they had not even a third of the capital, or number of workmen, employed that we had in Great Britain. In all cases where it could be shown to be an advantage to preserve human life, it ought to be the duty of the legislature to see it carried out. In other countries there was a much larger number of inspectors in proportion to the mines and people employed. It was well known that from accidents in mines from various causes, the loss exceeded 1,500 per annum. If any improvement which would reduce this by one-fifth—and more than this, from the evidence on the continent, was practicable—it would be a great benefit, not only to the working man and his family, but to the relief of the poor's rate, which persons who were not immediately connected with the mines had to pay.

Mr. J. ARTHUR PHILLIPS did not agree with the author of the paper that the mines of Great Britain were worse ventilated and less skilfully worked than those on the continent of Europe. He would instance the tin, copper, and lead mines of Devon and Cornwall as examples of well-ventilated and carefully worked mines, and was confident, from his own experience, that they would compare favourably with those of France, Germany, or any other country. It was true that in some instances inconvenience was experienced from want of proper ventilation, but this generally occurred in ends, or fire-breasts, where, until a communication could be effected with the other parts of the workings, a stagnation of air was liable to take place. Those in charge of the mines were, however, as a general rule, quite conversant with the principles on which a good supply of air depends, and were fully alive to the advantages to be derived from good ventilation, and where this could not be effected by the establishment of a natural draught, mechanical means were adopted. He was also of opinion that the health of the miner suffered as much from the sudden changes of temperature to which he was constantly subjected as from a want of ventilation in the mines. It was true that in certain exceptional cases, where carbonic acid gas was given off, the ventilation of metal-producing mines became deficient, and necessitated peculiar precaution. As an illustration of this fact he would state, that when the Pranal pumps at the Pontgibaud Mines, were first set in motion, after a stoppage of some years, the water issuing from the shaft was so impregnated with carbonic acid gas as to effervesce with great violence on reaching the surface, and on flowing into the river caused the death of multitudes of small fish from the same cause.

Mr. HALL begged, on the part of an important class of operatives in this country, to express his thanks to Dr. Chambers for the prominent part he had taken in the question of Industrial Pathology, and for the able manner in which he had brought forward the importance of maintaining, as far as possible, an upright posture of the body in all manual operations. He was happy to

say that in the branch of trade (shoemaking) with which he was connected, the suggestions had been carried out, to a great extent, and with the most beneficial results to the workmen, by whom the system was very highly appreciated, as they could do more work, and with greater ease to themselves, than under the old system of a cramped position whilst at work.

Mr. J. A. PHILLIPS said, that with regard to the progressive increase of temperature in mines as we went further from the surface, he did not consider this phenomenon to be wholly dependent on their depths. It was well-known that tin and lead mines of a given depth were never so bad as copper mines of the same depth, and he believed this difference of temperature depended entirely on chemical influences. He had always observed that the warmest places in mines were invariably in the vicinity of large quantities of either iron pyrites or copper pyrites in a state of rapid decomposition. By this decomposition the sulphates of these metals were produced, whilst a considerable elevation of temperature was the result of the chemical action.

Mr. CONYBEARE fully agreed with Mr. Phillips, and it was the case with all precipitate works. With regard to copper mines, by the pumping operation, great quantities of water were washed out. The copper was precipitated, and the sulphide destroyed by the chemical action. With regard to the Cornish mines, he believed they were well worked in respect of ventilation, but the present means of ascending and descending the mines were fraught with the greatest danger to the miners. In one or two instances man-lifts were employed, but, generally speaking, miners were a class of men who did not like anything new, and would prefer climbing up and down the enormous depths they did, to being hauled up by means of a good steam apparatus. In some of the mines the labour of ascending and descending was equivalent to a man walking fifteen miles a-day to his work, and if the talented author of the paper could suggest a simple and economical means of obviating that amount of physical labour, he would confer a great benefit upon the mining community.

The CHAIRMAN said they must not lose sight of the obligations they were under to Mr. Mackworth, and he begged to move a vote of thanks to that gentleman for the valuable and important paper which he had brought before them that evening. He hoped it would lead to the subject being followed up by others, if not with equal ability, at least in a way to be of great value and importance.

Mr. MACKWORTH said, in replying to the remarks which had been made in the discussion, he must express his satisfaction that so many gentlemen had taken it up, as he was persuaded that very much good would be effected by, as the phrase went, "ventilating" the subject of the diseases of miners. He had alluded in his paper to the ventilation of Cornish mines, and by that (after having been down many Cornish mines) he was prepared to take his stand. The chief defect in their ventilation was the communication left between a number of shafts, which cut it off. He did not agree with Mr. Conybeare, that the ventilation had little to do with the short lives of the Cornish miners as compared with the ladders. There was so small a difference in the lives of miners in different parts of England, that we must look for some general cause pervading all mines as the cause of mortality, and that was working in advance of the air. He quite agreed with the remark as to Government interference being undesirable; but when a man was needlessly injured, whether it be by the fault of his employer, ensuing in his death or in crippling him for life, it was surely just as much deserving of the interference of the law as reckless trading, or cruelty to animals. By the same rule of passive inspection only, all the powers of sanitary laws should be abolished. In mines the men were peculiarly in the power of the manager, and yet it had been shown, in the experience of the last four years, during which nearly 4,000 lives had been sacrificed in coal-mines, not to speak of the 40,000 other serious accidents, that, as regarded the condition of the miner, criminal and civil laws were almost completely inoperative. They would not go under ground In no instance in England, he believed, had the charge of manslaughter been sustained against a manager, nor had the widows or children of the men killed been able to recover any damages. Hardly ever was any effort made to compensate them in their distress. The managers of mines enjoyed practically a perfect immunity from all legal responsibility. He intended to have omitted accidents altogether from consideration, but he might state that, from published Government Returns, the mortality from accidents was, in the coal-mines of

	Killed. Persons.
Prussia	1·89 per 1,000 per ann.
Belgium	2·8 „ „ „ „
England	4·5 „ „ „ „
Staffordshire	7·3 „ „ „ „

He had spoken decidedly as to the difficulty of persuading persons to adopt sanitary measures, as he found it next to impossible to induce proprietors of mines to adopt remedies for the most obvious dangers, and afterr epeated accidents had occurred from the want of them. The Inspectors of local mines had been engaged on persuasion on a great scale, and the result was, that the number of accidents, though not the number of deaths, was increasing Government interference could not be said to have prejudicially affected Belgium, for the production of coal was half as much again as in England per acre of the coal-field, and the production was still increasing at about 10 per cent. per annum, whereas, in England, the highest estimate was 5 per cent. Experience had shown that the cotton manufacture and railways, contrary to most sage predictions of utter ruin, had increased much more since Government interference commenced. As to the benefit, let the operatives and the travelling public speak. Commercial transactions were hedged round by every possible sort of legislation, because the persons affected were on an equality. But a miner could not obtain any protection whatsoever for his life or his health, except by leaving his employment; and this was lauded as a free use of the capital of labour. It would be equally satisfactory to tell a person travelling by railway that, as he was not satisfied with the safety of the line, he must travel by another. All sanitary measures had passed over the mines as if 300,000 of the most valuable part of our population were to be forgotten. The education of the mining population was of the highest importance. They had begun to understand the causes which had weighed them down. They ought to have a voice, and certainly the chief one, in any legislative measures. It was *their* property in their labour which had been curtailed, although their want of information might not have taught them that care on the part of the managers would have prolonged their lives. In conclusion, he believed he had advanced no statements but such as could be amply substantiated, and made no proposal which would increase the cost of mining, or check its development, but the contrary. The subject was one still more important, from the magnitude of the evil, than the accidents in mines. It could not be in better hands than the Society of Arts.

The Secretary announced that the paper to be read at the meeting of Wednesday next, the 11th inst., was on "The Mineral Industries of the United Kingdom," by Mr. Robert Hunt, F.R.S.

To Correspondents.

V. B. is informed that the circumstance alluded to in his note has never come within the knowledge of the Secretary.

MEETINGS FOR THE ENSUING WEEK.

TUES. Syro-Egyptian, 7½. 1. Mr. Bonomi, "On the Assyrian Deity Nisroch." 2. Dr. Beniseh, "On the Cuthite Idol Nergal."
Med. and Chirurg., 8½.
Zoological, 9.

WED. Literary Fund, 3.
Society of Arts, 8. Mr. Robert Hunt, F.R.S., "The Mineral Industries of the United Kingdom."
Graphic, 8.
Ethnological, 8½.

FRI. Astronomical, 8.
Botanical, 8.
Philological, 8.

SAT. Royal Botanic, 3½.
Medical, 8.

PARLIAMENTARY REPORTS.

SESSIONAL PRINTED PAPERS.

Delivered on 24th and 26th March, 1855.

132. Committee of Selection—6th Report.
135. Publication of Intelligence (Crimea)—Copy of Letter.
61. Bill—Criminal Justice.
Epidemic Cholera (General Board of Health)—Report on the results of the different methods of treatment.
Australian Colonies (Alterations in the Constitutions)—Further Papers.

Delivered on 27th of March, 1853.
Session 1854.

524. Chapels, &c., Abroad—Return.

Delivered on 28th of March, 1855.

119. Clergy Reserves (Canada)—Copy of Act.
110. Local Acts (16, Hoarwithy Bridge; 17, South Wales Railway 18, Maryport and Carlisle Railway; 19, Newcastle upon Tyne, New Streets and Improvements; 20, Gateshead Quays and Improvements;)—Reports from the Admiralty.
Turnpike Trusts—1st Report by the Secretary of State, with Abstract of Accounts.

Delivered on 29th of March, 1855.

98. (1). Staff Officers—Supplemental Return.
129. Bankruptcy—Abstract of Return.
136. Regimental Commissions—Return.
139. Committees of Selection—Seventh Report.
141. Mr. Kennedy—Return.
75. Wrecks—Return.
65. Bills—Registration of Births, &c. (Scotland).
66. Bills—Affirmations (Scotland).
68. Bills—Convention with Sardinia.
Public General Acts—Caps. 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10.

Delivered on 30th March, 1855.

89. Coroners' Inquests—Abstract Return.
134. Jurors—Abstract of Returns.
142. Public Debt—Account.

PATENT LAW AMENDMENT ACT, 1852.

APPLICATIONS FOR PATENTS AND PROTECTION ALLOWED.

[*From Gazette, March 30th*, 1855.]

Dated 18th December, 1854.

2661. W. Gilpin, 2, Moorgate-street, and A. Bowen, Stafford-stree Peckham—Prevention of smoke.

Dated 17th January, 1855.

126. J. Slack, Manchester—Woven fabrics.

Dated 16th February, 1855.

351. R. A. Brooman, 166, Fleet-street—Preparing certain fibres for manufacturing purposes. (A communication.)

Dated 28th February, 1855.

432. T. Helliwell and J. Barker, Todmorden—Preserving pickers and picker-sticks, and preventing cops being knocked off in weaving.

Dated 10th March, 1855.

541. A Clark, Gate-street, Lincoln's-inn—Globes.
543. J. Hughes, Newport, Monmouthshire—Bushing touch-holes of cannon.
544. C. Heaven, Hull—Machinery for embroidering fabrics.
545. A. E. L. Bellford, 32, Essex-street, Strand—Machinery for making butt-engines at one operation. (A communication.)

Dated 12th March, 1855.

547. J. Malcomson and R. Shaw, Portlaw, and W. Horn, Mark-lane—Expansion valves.
549. J. Brookes, Birmingham—Waistcoat.
551. G. Mosley, Southwark—Buttons.
553. W. P. Stanley—Peterborough—Clod crushers.
555. J. M. Napier, York-road—Furnaces used in the manufacture of soda or alkali.

Dated 13th March, 1855.

559. T. W. Willett, 25, Belsize-road, St. John's wood—Swimming belts.
561. J. Gracie, Stanley-terrace, Rotherhithe—Wood-planing machines.
563. C. Iliffe, Birmingham—Manufacture of metallic rods, bars, and tubes.

Dated 14th March, 1855.

564. R. C. G. Cooke, New Swindon—Cloaks.
565. G. Riley, 12, Porland-place North, Clapham-road—Starch or grape sugar.
566. H. Gray, 60, Clement's-lane, Strand—Substitute for flock.
567. B. Goodfellow, Hyde—Regulating the power for driving pumps of hydraulic presses.
568. R. Neale, Cincinnati, U.S.—Copper-plate printing.
569. J. Kidder, Plaistow—Castors.
570. W. and J. Galloway, Manchester—Regulating the pressure on slide valves of steam-engines.
571. J. Marland, Walsden — Rollers for spinning and other machinery.
573. W. Soelman, 3, Bennett-street, Fitzroy-square—Propellers.
574. E. J. Mitchell, Bradford—Rollers in washing wool and linen.
575. J. Turner, Farringdon-street - Coffin furniture.
576. J. Bernard, Club-chambers, Regent-street—Boots and shoes.
577. C. Goodyear, jun., Paris—Plates of artificial teeth.
578. R. Wright, Richmond, York—Swords.
579. A. Davis, Tottenham Court-road—Polishing powder.
580. J. Hetherington, Manchester, and A. Vickers, Bristol—Spinning machinery.
581. W. Lister, Richmond, Yorkshire—Implement for raising roots in the ground, &c.

Dated 15th March, 1855.

582. H. Bach, Sheffield—Sash frames.
584. R. M. Butt, Fairfield works, Bow—Night-lights.
585. E. Humphrys, Deptford—Applying heat to steam-boilers.
586. F. Loret-Vermeersch, Malines—Stopping trains on railroads.
587. W. Monday, jun., Kingston-upon-Hull—Preparing plumbago, graphite, &c., for polishing and lubricating, &c.
588. G. Grignon, 13, Sutherland-square, Walworth—Detaching boats from ships' sides.
589. H. Wickens, 4, Tokenhouse-yard—Communicating signals in railway trains.

Dated 16th March, 1855.

590. J. Mitchell, Sheffield—Supplying grease to engines.
591. W. Hill, Birmingham—Metallic pens and penholders.
592. M. Smith, Heywood—Looms.
593. J. W. C. Wren, Tottenham Court-road—Invalid bed.
594. T. Picton, Liverpool—Scaffoldings.
595. W. Winstanley and J. Kelly, Liverpool—Force pumps.
596. A. Mauduit and F. H. Ouin, Paris—Hydraulic machine.
597. Sir W. Burnett, Somerset house, and J. W. D. Brown, R.N., Haslar Hospital, Gosport—Constructing signal lanterns.

Dated 17th March, 1855.

598. T. Petitjean and — Pitre, 45, Upper John-street, Tottenham Court-road—Daguerreotype-plates. (A communication.)
599. E. Breittmayer, Paris—Mortising machine.
600. J. H. Johnson, 47, Lincoln's-inn-fields—Application of carbonic acid gas as a motive power. (A communication.)
601. J. H. Johnson, 47, Lincoln's inn-fields—Steam-engines. (A communication.)
602. J. H. Johnson, 47, Lincolns'-inn-fields—Steam pressure and other indicators. (A communication.)
603. T. G. Shaw, Old Broad-street—Facilitating the 'tilting' of casks.
604. B. Britten, Anerly—Projectiles.

Dated 19th March, 1855.

606. G. Lowry, Manchester—Lubrication.
608. E. R. Tayerman, 79, Pall Mall—Portfolios.
610. V. Scully and B. J. Heywood, Dublin—Regulating supply of gas to gas burners.
612. F. A. Chartraire, Paris—Fastening gloves, collers, &c.
614. L. H. Crudner and F. L. Koebrig, Tottenham Court-road—Ventilation.
616. R. E. Hodges, Southampton-row, and C. Murray, Manor-place, Walworth—Door springs.
618. W. Smith, Little Woolstone, Fenny Stratford—Ploughing.

WEEKLY LIST OF PATENTS SEALED.

Sealed March 30th 1855.

2123. William M'Naught, Rochdale—Improvements in slide-valves for steam-engines.
2130. David Chalmers, Manchester—Improvements in the mode or method of working railway breaks and communicating signals.
2147. John Macmillan Dunlop, Manchester—Improvements in machinery or apparatus for preparing, spinning, and doubling cotton and other fibrous materials.
2149. Andrew Smith, Princess-street—An improved safety cage and apparatus for miners.
2168. George Wigzell Knocker, Bushy-ruff, Dover—Improvements in obtaining motive power by means of water.
2222. Jacob Dockray, Leeds, and John Dawson, Holbeck, Leeds—Improvements in machinery for raising woollen cloth.
2467. Robert Gibson, Hunslet, Leeds—Improvements in machinery for carding wool, flax, cotton, and other fibrous materials.—(A communication.)
2647. Daniel Chandler Hewitt, Richmond—Improvements in the construction of pianofortes.
2684. William Milner, Liverpool—Improvements in safes and other such depositories, and further improvements in the locks of the same.
2707. Edward Loysel, Rue de Grétry, Paris—A new game combining chance and skill, and the apparatus to be used therewith.
156. Scipion Salaville, Paris—An improved method of preserving and purifying grain and seed.
221. Thomas Binks, Wentworth—Improvements in raising and regulating the supply of water and other fluids.